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Comparative Study of Pillar Load Transfer Associated With Multiple-Seam Mining

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UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 9176

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	psi/ft	pound per square inch per foot
in	inch	psig	pound per square inch, gauge
pct	percent	yr	year
psi	pound per square inch		

COMPARATIVE STUDY OF PILLAR LOAD TRANSFER ASSOCIATED WITH MULTIPLE-SEAM MINING

By R. J. Matetic[1] and G. J. Chekan[1]

ABSTRACT

The Bureau of Mines, as part of a program to improve mine planning and development, is currently investigating the effects of pillar load transfer, which can impact mining operations within a multiple-seam configuration. A comparative study was performed at two separate mine sites. The objective of this study was to compare two mines, each affected by this pillar load transfer mechanism, and to show how this interaction affected underground workings by the installing and monitoring underground instrumentation. At mine site A where the overburden was 1,000 ft, the innerburden thickness was less than a pillar width (40 to 45 ft), overlays of the mine layout show pillars were not superpositioned, excessive roof to floor convergence was measured, and pressure readings indicated pillar core loading only.

At mine site B, the overburden was approximately 555 ft, the innerburden thickness was approximately 105 ft, overlays of the mine layout show pillars were superpositioned, minimal roof to floor convergence was measured, and pressure readings indicated a skin loading only.

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INTRODUCTION

The mining of two or more contiguously placed coalbeds either simultaneously or separately is widely practiced throughout the United States. A survey of multiple-seam mining in the United States reveals that 156 billion short tons of coal lie in a multiple-seam configuration, representing 68 pct of the U.S. coal reserves. Most of this coal occurs in eight States --Colorado, Illinois, Kentucky, Ohio, Pennsylvania, Utah, West Virginia, and Wyoming (1).[2] This percentage of minable reserves emphasizes the importance of resource conservation and recovery; methodologies and techniques must be developed that will allow safe and economical extraction.

The mining of adjacent coalbeds either simultaneously or separately can lead to strata interaction effects if certain parameters are not considered. A strata interaction, which utilizes load transfer, is critical to upper or lower mine workings and is termed pillar load transfer. This pillar load transfer interaction occurs particularly when coalbeds are in close proximity, less than 110 ft (2-4), and either isolated, remnant pillars (barriers) or many strong, competent pillars are present in the upper workings. These conditions may serve to concentrate stresses in the innerburden causing ground instability in the upper or lower workings (fig. 1).

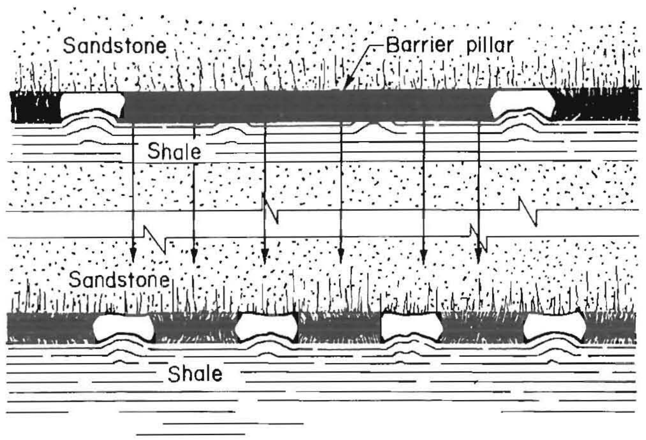

FIGURE 1.–Pillar load transfer interaction. The arrows represent the load being transferred from the upper to lower workings.

The interaction of pillar load transfer can be classified into two parameters. These are fixed parameters that are controlled by the geologic environment; and engineering parameters that could be controlled by proper mine design. The fixed parameters, which are critical to this study, include overburden depth, innerburden thickness, and the physical characteristics associated with the surrounding strata. The engineering parameters that are critical include seam sequencing and superpositioning of pillars. Table 1 shows the fixed and engineering parameters for both study mines.

[2]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

TABLE 1. - Fixed and engineering parameter information for study mines A and B

	Study mine A	Study mine B
FIXED PARAMETERS		
Depth of overburden, ft:		
Upper coalbed	960	445
Lower coalbed	1,000	555
Innerburden:		
Thickness..........ft..	40	110
Sandstone..........pct..	77	6
Number of innerbeds	3	3
ENGINEERING PARAMETERS		
Seam sequencing:		
Upper coalbed	June 1980	Nov. 1986
Lower coalbed	Dec. 1982	Dec. 1984
Superpositioning	No	Yes

The overall understanding of pillar load transfer and its effect on seam interaction is limited. Few attempts have been made to correlate or compare these parameters in relation to underground instrumentation and monitoring. The Bureau of Mines conducted this study at two separate mines to obtain a better understanding of pillar load transfer and how this interaction affects underground workings.

MINE LOCATIONS AND GEOLOGY

Study mine A is located in Raleigh County, WV (5) (fig. 2). The company is operating in two superimposed coalbeds. The upper mine is located in the Peerless Coalbed, which is approximately 72 in thick. The lower mine is located in the No. 2 Gas Coalbed, which is approximately 48 in thick. The mines are separated by approximately 40 to 45 ft of innerburden.

A generalized stratigraphic column of the study area is shown in figure 3. The overburden consists predominantly of sandstone with innerbedded shale units of varying thickness. The innerburden also consists of a predominant sandstone with some innerbedded shale units.

Study mine B is located in Saline County, IL, (fig. 4). The company also

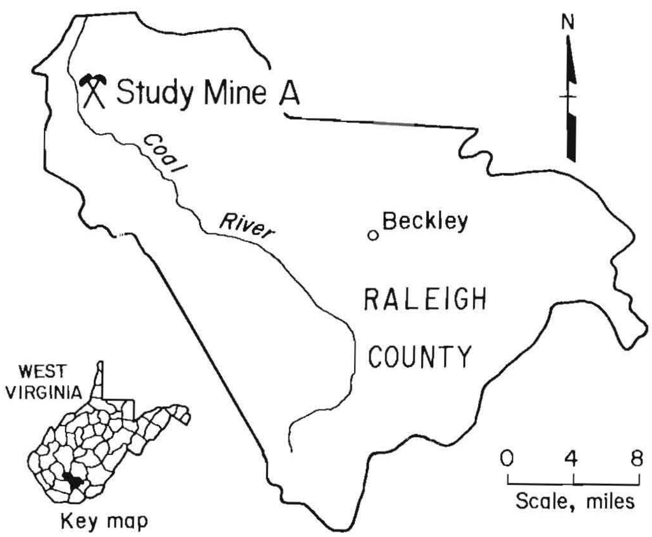

FIGURE 2.–Location of study mine A.

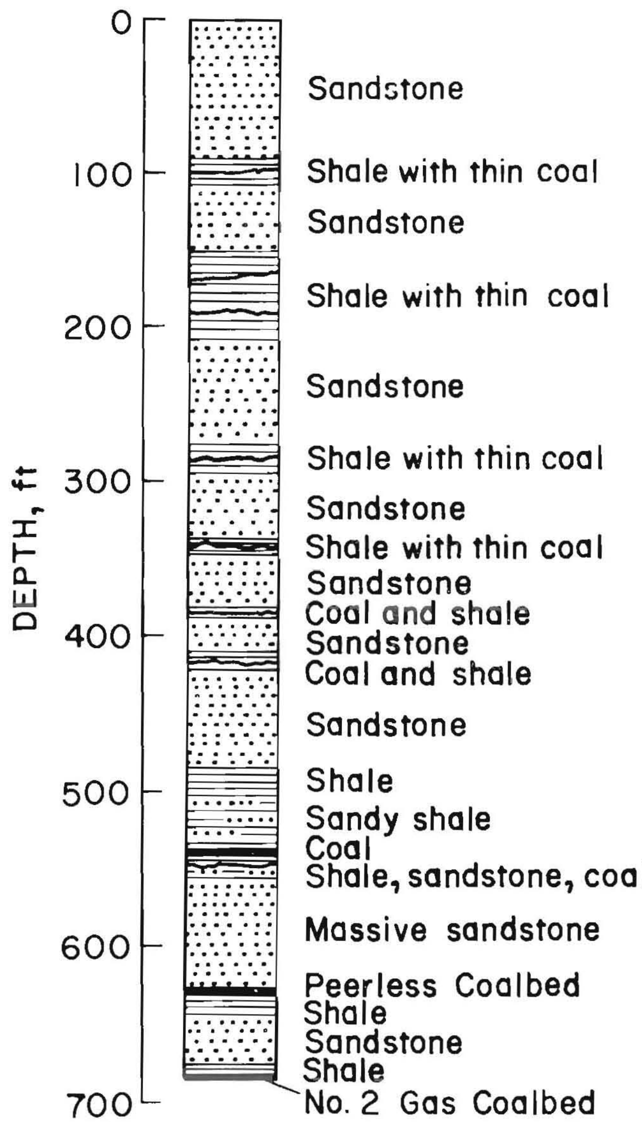

FIGURE 3.–Generalized stratigraphic column of study area at study mine A.

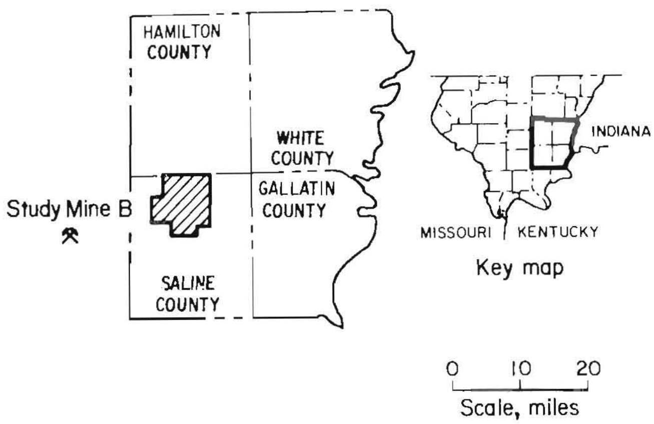

FIGURE 4.–Location of study mine B.

is operating in two superimposed coalbeds. The upper mine is located in the Herrin No. 6 Coalbed, which is approximately 72 in thick. The lower mine is located in the Springfield No. 5 Coalbed, which is approximately 82 in thick. The innerburden separating the two mines is approximately 100 to 120 ft thick.

A generalized stratigraphic column of the study area is shown in figure 5. The overburden consists mostly of sandstone and shale with limestone and siltstone units interbedded. The innerburden is comprised mostly of shale with an innerbedded sandstone unit.

FIXED PARAMETERS

DEPTH OR OVERBURDEN

Depth in relation to all room-and-pillar mining operations is critical as overburden increases (3). Figure 6 displays an overburden isopach map for study mine A in relation to the study site for the lower coalbed. The overburden above the study site reaches a topographic high of approximately 1,000 ft and with 40 ft of innerburden, overburden depth above the upper coalbed reaches approximately 960 ft.

Figure 7 represents an overburden isopach map of study mine B for the upper mine in relation to the study area. The overburden depth above the upper mine is approximately 445 ft and with approximately 110 ft of innerburden, overburden to the lower mine is nearly 555 ft, considerably less than that of study mine A.

To obtain a better understanding of depth and its relation to underground workings, figure 8 was plotted showing the relationship between upper seam depth versus innerburden thickness for the upper mine of both study mines. A theoretical cutoff is shown on the plot to demonstrate the effect of increasing depth on mine opening stability (3). Study mine A, with an overburden depth of 960 ft and an innerburden thickness of 40 ft, falls well within the unstable range. Whereas, study mine B, with an overburden depth of 445 ft and an innerburden thickness of 110 ft, falls within the stable range. This particular figure was constructed from a rather limited data set and is not necessarily conclusive owing to a shortage of information regarding greater depths with larger innerburden intervals (3). Also, this graph does not consider pillar or entry design. The primary purpose was to compare fixed information regarding both study mines.

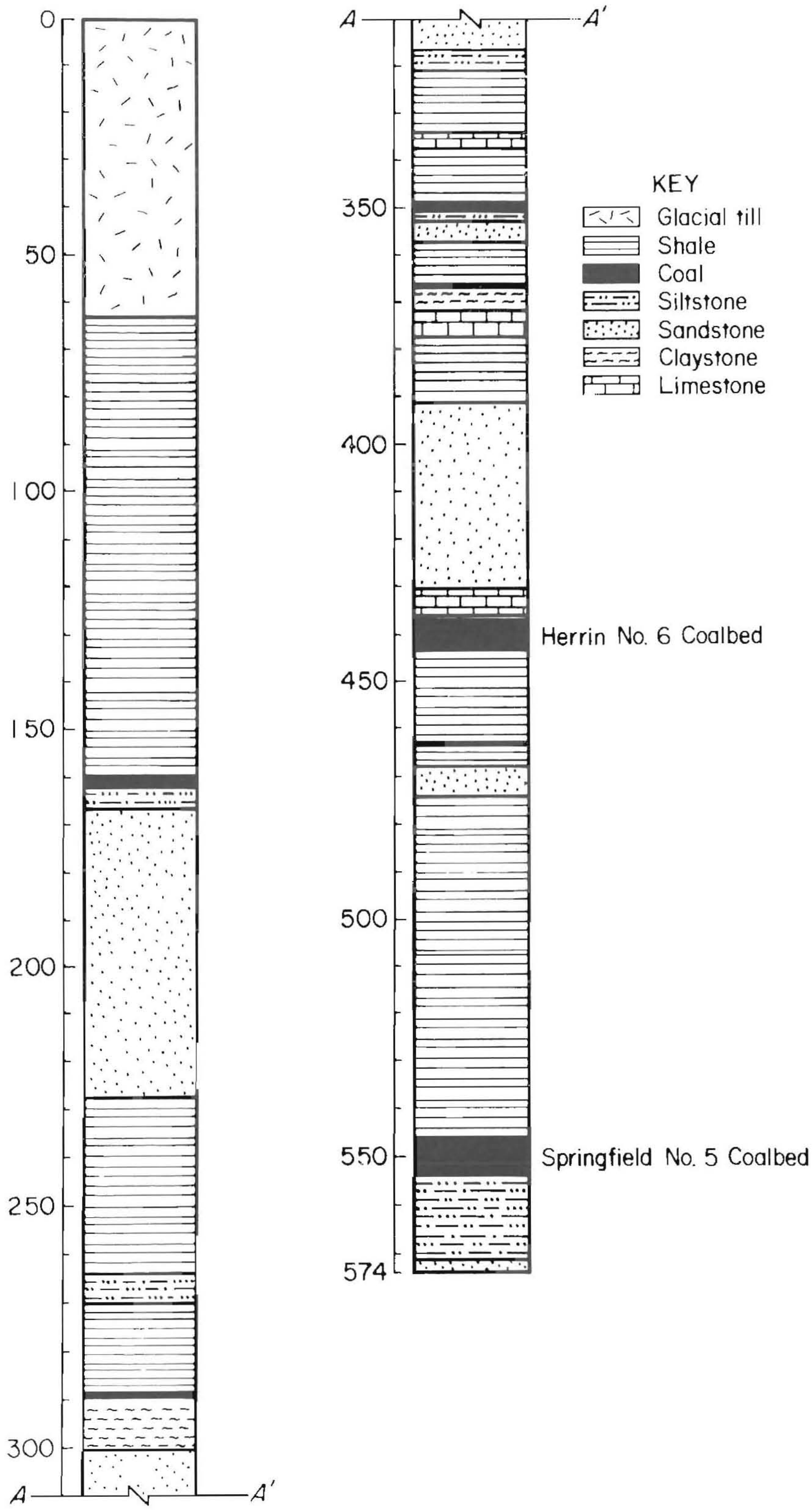

FIGURE 5.–Generalized stratigraphic column of study area at study mine B.

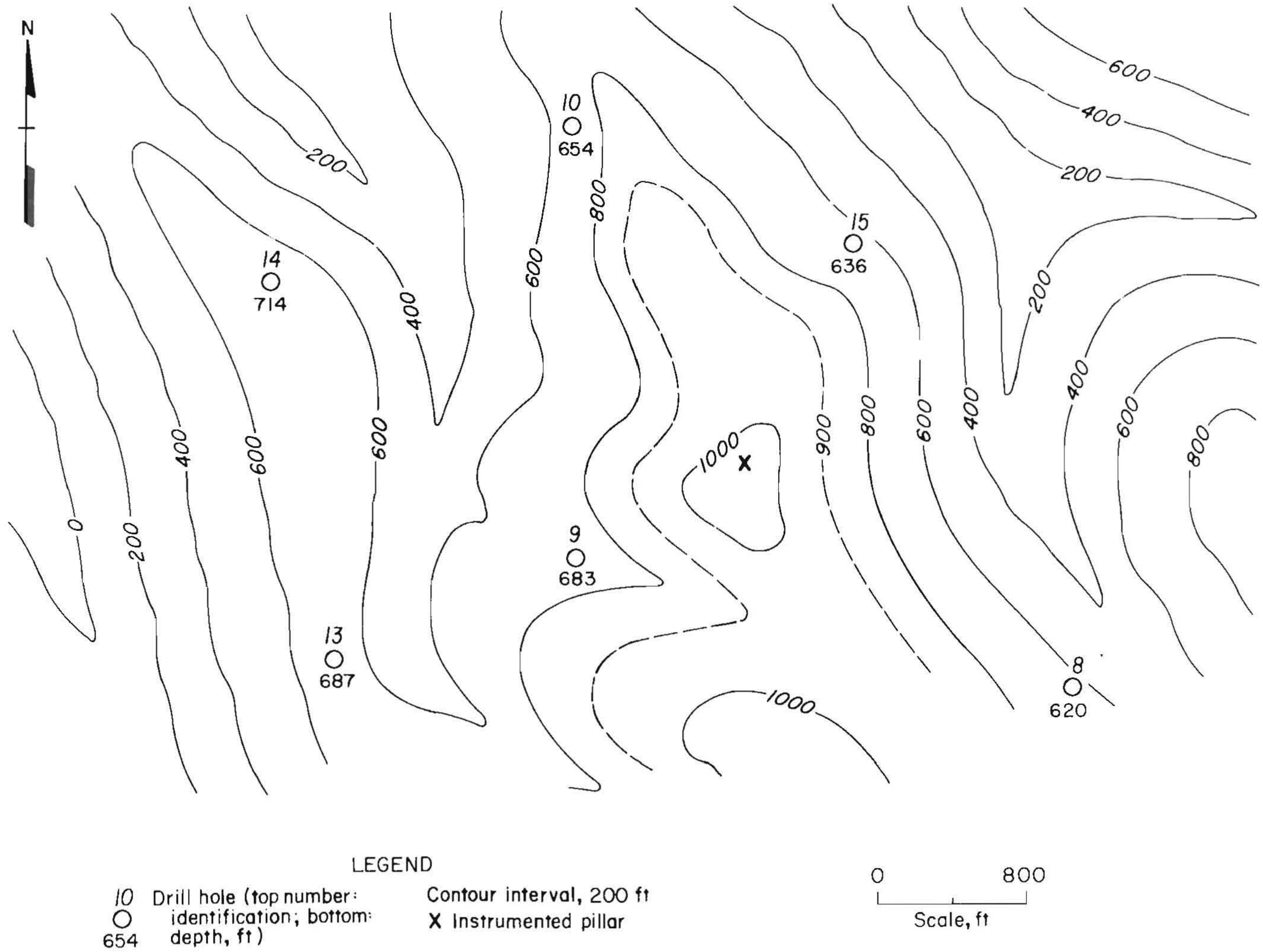

FIGURE 6.–Overburden isopach map of lower coalbed for study mine A.

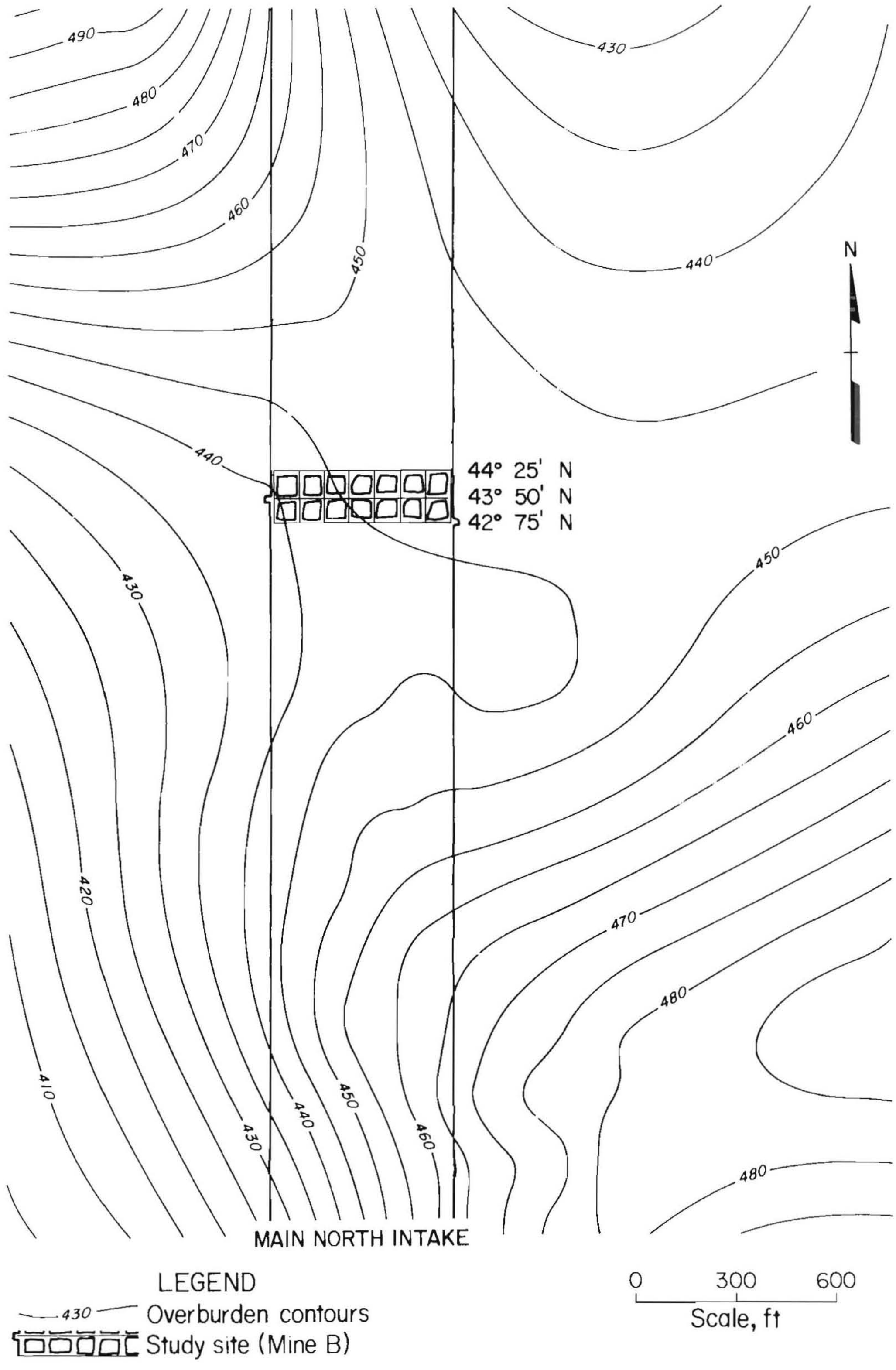

FIGURE 7.–Overburden isopach map of upper coalbed for study mine B.

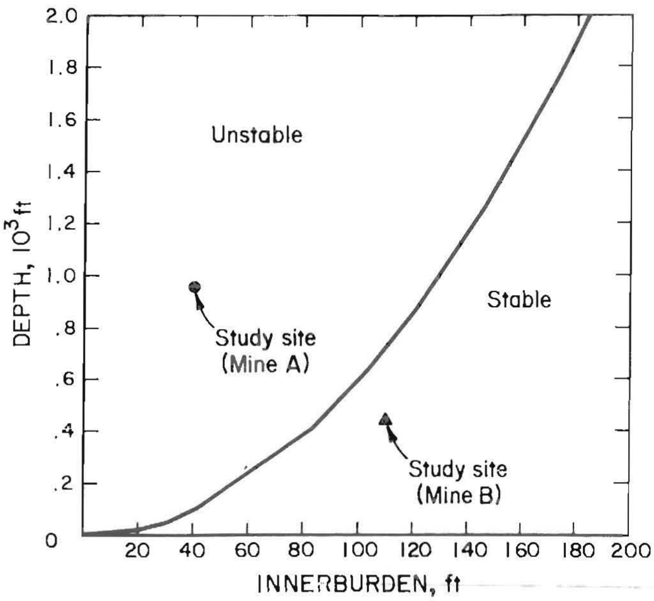

FIGURE 8.–Upper seam depth versus innerburden thickness for study mines A and B.

INNERBURDEN THICKNESS AND PHYSICAL CHARACTERISTICS

Innerburden Thickness

The thickness of innerburden between two coalbeds is critical when associated with multiple-seam mining. Pillar load transfer from overlying workings represents a major problem, especially where the two coalbeds are fairly close together (4). Figures 9 and 10 represent innerburden isopach maps for study mines A and B, respectively. Study mine A was estimated to have approximately 40 ft of innerburden at the study site whereas, study mine B has considerably more innerburden thickness (105 ft) at the study site. An innerburden that is small in thickness, as in mine A, would tend to transfer load more readily as compared to an innerburden that is greater in thickness, as is the case at study mine B.

Physical Characteristics

Percentage of Sandstone

The amount of sandstone or rock type with a high modulus of elasticity, located within the innerburden, is a critical parameter in pillar load transfer interaction. A rock type with a high modulus of elasticity would tend to lessen load transfer within the innerburden, whereas a rock type containing a low modulus of elasticity tends to enhance this interaction process.

Figure 11, which was constructed from 25 room-and-pillar case studies (4), displays a relationship between innerburden thickness and percentage of sandstone. According to Haycocks (4), and using the equation

$$I = 110 - 0.42S,$$

where I = innerburden spacing, in feet, above which no interaction damage may be expected from room-and-pillar mining.

and S = sandstone percentage located within the innerburden, a limit on the interactive distance could be obtained based on the lithology of the innerburden.

By using the generalized stratigraphic columns for both study sites (figs. 3 and 5), the sandstone percentage of 77 pct was calculated for study mine A and 6 pct for study mine B.

By substituting the sandstone percentage for mine A, the interactive distance is calculated to be as follows:

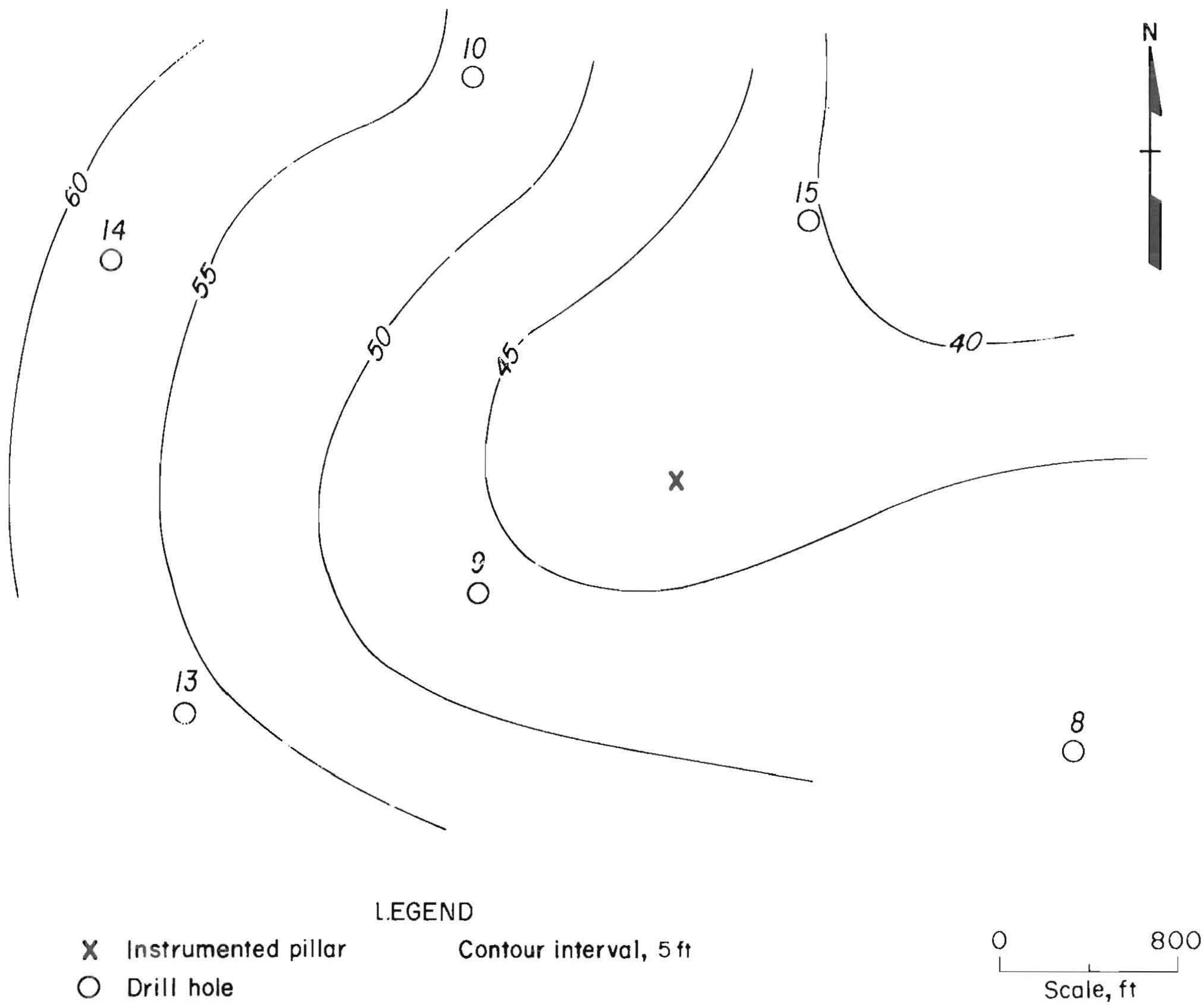

FIGURE 9.–Innerburden isopach map for study mine A.

$$I = 110 - 0.42(77)$$

$$= 78 \text{ ft},$$

and performing the same calculation for mine B, the interactive distance is

$$I = 110 - 0.42(6)$$

$$= 107 \text{ ft}.$$

According to Haycocks (4), approximately 78 ft would be the innerburden spacing above which no interaction damage may result from room-and-pillar mining for mine A and 107 ft would be the innerburden spacing for mine B. As mentioned previously, the innerburden spacing of mine A with respect to the study site was approximately 40 ft and the innerburden

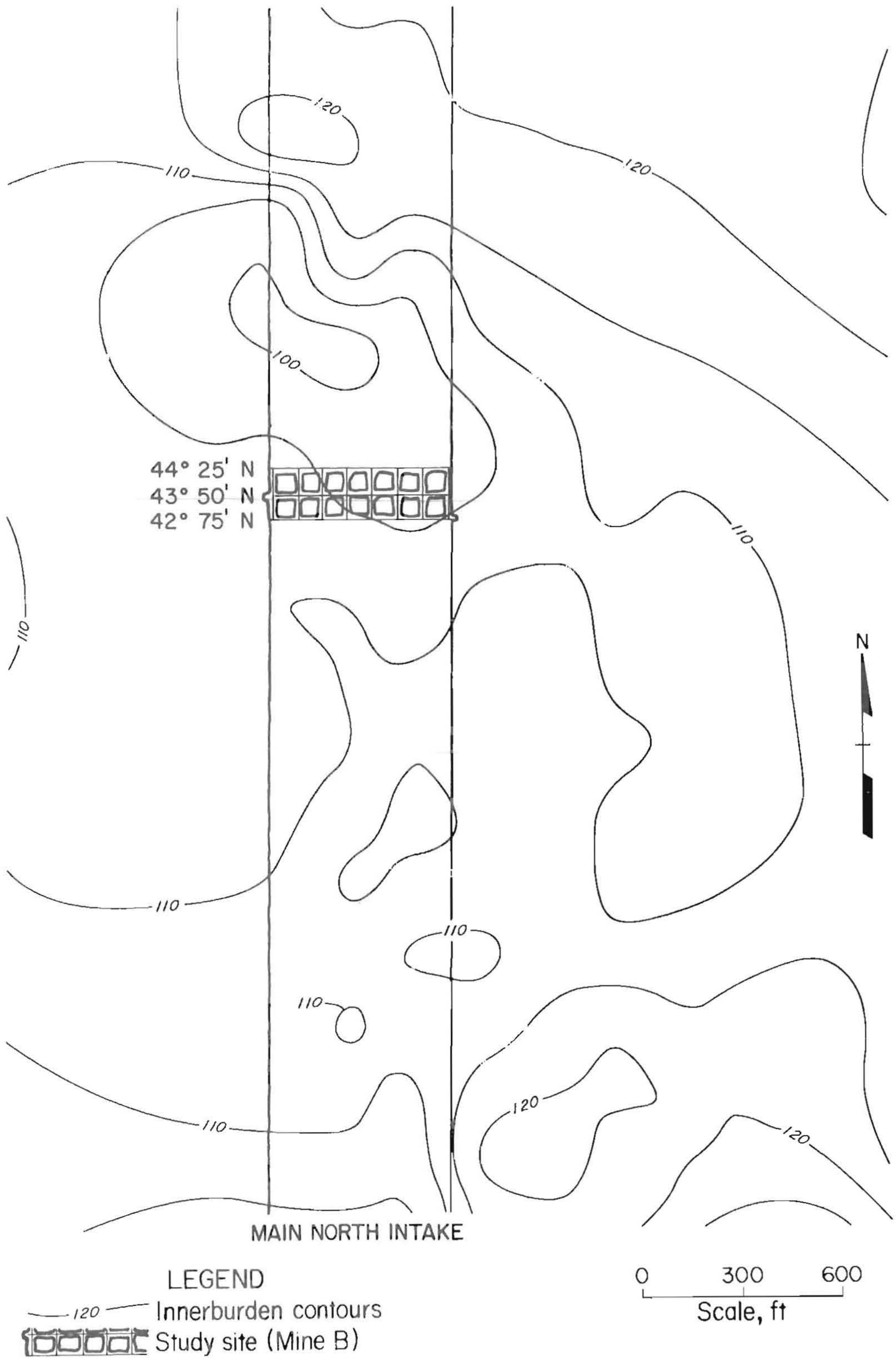

FIGURE 10.–Innerburden isopach map for study mine B.

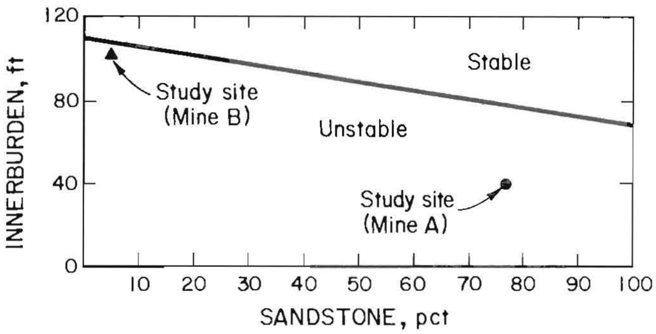

FIGURE 11.–Innerburden thickness versus percent sandstone for study mines A and B.

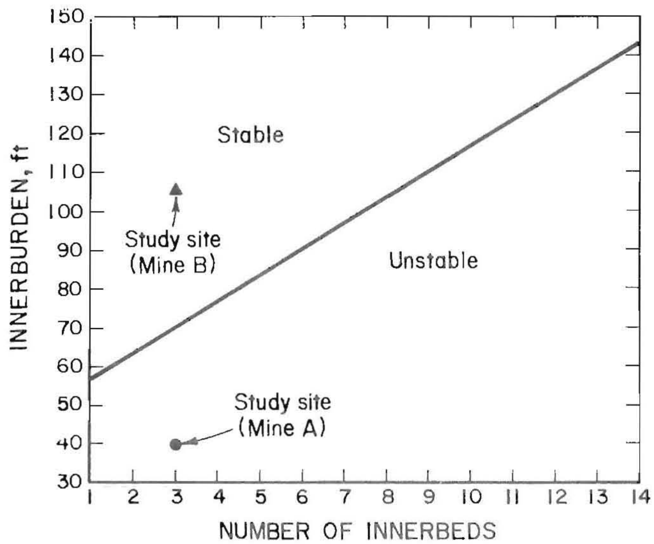

FIGURE 12.–Innerburden thickness versus number of innerbeds for study mines A and B.

spacing for mine B at the study site was approximately 105 ft.

Figure 11 also shows the location of the study sites for both mines A and B in relation to innerburden spacing versus percent sandstone. The mine A study site falls well within the unstable range, whereas the mine B study site also falls within the range of being unstable, but is very close to the theoretical cutoff of stable versus unstable. Although mine B has only 6 pct of sandstone located within the innerburden, the 105-ft innerburden thickness is a fixed parameter and may be contributing to the lack of problems at this site. Again, this graph was derived from a rather limited data set and it does not represent all stable and/or unstable mining conditions.

Number of Innerbeds

Through the use of photoelastic models, Ehgartner (6) determined that the interactive distance is a function of the degree of layering or number of innerbeds. Figure 12 is a plot representing innerburden thickness versus number of innerbeds. Mine A has three discrete stratigraphic units located within the innerburden with respect to the study area. There is a sandstone layer, which is interbedded between two shale layers. With three innerbeds and an innerburden thickness of approximately 40 ft, the study site for mine A fell well within the unstable range on the plot. Mine B, with respect to the study area, also encountered three distinct innerbeds. There also is a very small sandstone layer occurring between two large shale layers. With three innerbeds and an innerburden thickness of 105 ft, mine B at the study area fell well within the stable range. Again, these plots were used for comparison purposes and do not represent all stable and/or unstable mining conditions.

MINING ENGINEERING PARAMETERS

SEAM SEQUENCING

Seam sequencing is an engineering parameter that is critical to multiple-seam design. The upper coalbed area for mine A was driven in June 1980, and the same section located in the lower coalbed was driven in December 1982, 2.5 yr later. Load concentration and transfer through pillars in overlying operations can occur when the upper seam is mined first and some pillars are left unmined. Typical problems that could occur include floor heave, pillar crushing and failure, rib spalling, and roof failure (7-11). Major floor heaving and excessive pillar loading at mine A were observed within the lower coalbed in October 1984. Approximately 3 to 4 months later, the upper coalbed experienced excessive entry convergence and pillar loading. Figure 13 displays major floor heaving and rib spalling that occurred in the lower coalbed of study mine A.

The mining sequence for mine B at the study area was similar to mine A, but the lower coalbed was extracted first. The lower coalbed in relation to the study area was driven approximately December 1984, and the same section located in the upper coalbed was driven in November 1986, approximately 2 yr later. No major ground problems existed in the upper or lower coalbeds.

SUPERPOSITIONING OF PILLARS

Superpositioning of pillars in upper and lower workings should be standard practice in areas that may be prone to pillar load transfer. Superpositioning of pillars decreases the effects of load transfer. Figures 14 and 15 shows the practice of superpositioning for both study areas of mines A and B, respectively.

Both mines did attempt to superimpose their pillars and some error could be attributed to surveying, drafting, etc. Figures 14 and 15 were constructed from the information provided by each company. Therefore, using the information obtained, the pillars in mine A are not superpositioned, whereas the pillars in mine B are superimposed.

Peng (12) developed a simplified model representing pressure interaction between superpositioned pillars (fig. 16). A uniform loading of the overburden is shared equally by the upper coalbed pillars and, in return, they transmit the load to the floor. Although the pressure transmitted to the pillars is uniform, the load transmitted to the floor is not. A higher pressure develops within the plane where the pillar meets the floor. This pressure decreases downward and dissipates at a distance approximately four times the pillar width. The pressure contours (fig. 16) simulate bulbs. These same contour lines are expected to be in the roof immediately above a

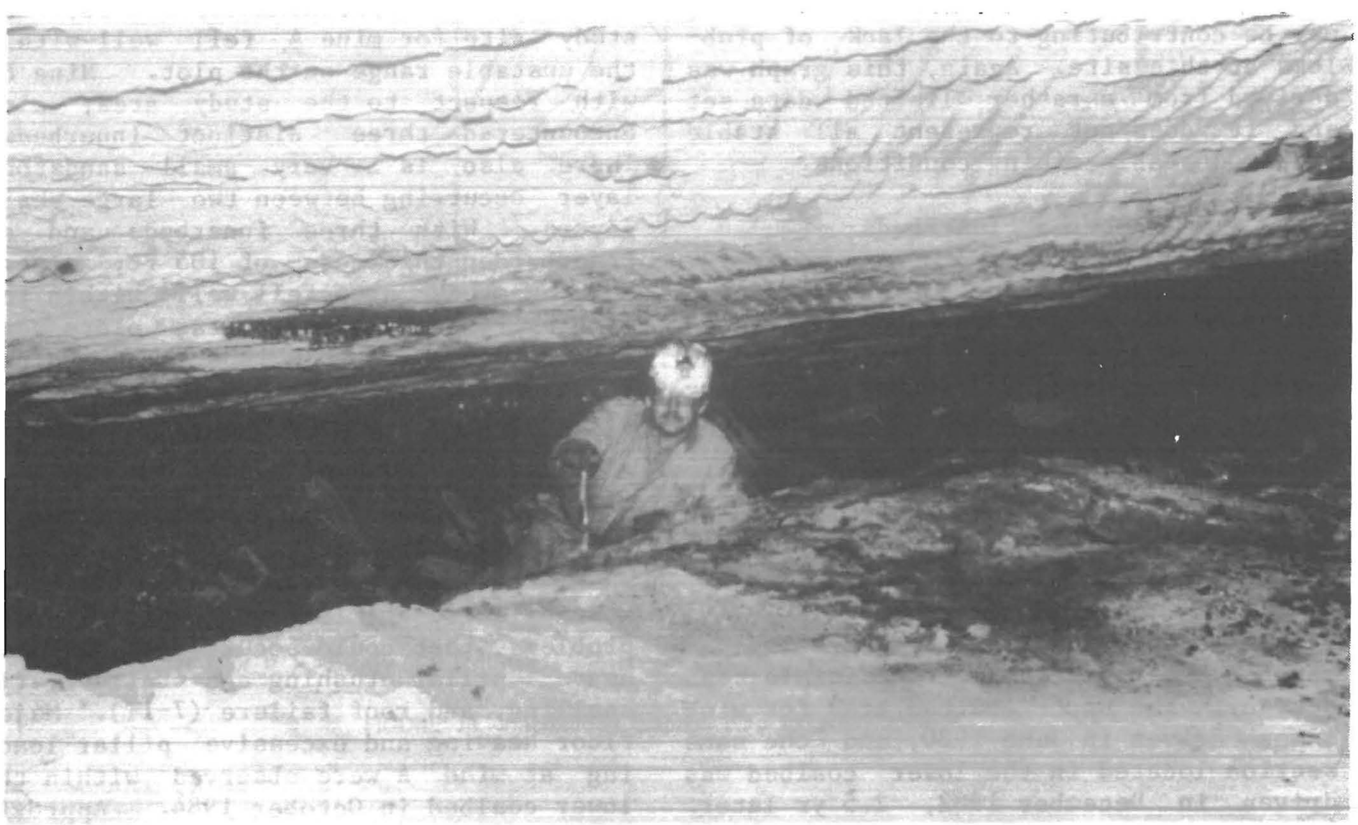

FIGURE 13.—Major floor heaving and rib spalling occurring in the lower coalbed of study mine A.

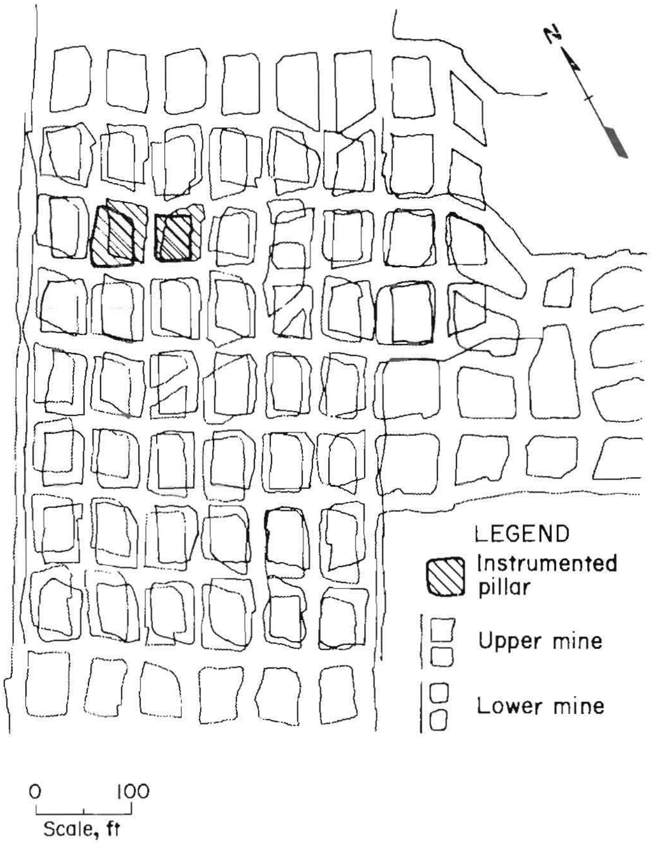

FIGURE 14.–Superpositioning of instrumented pillars at study mine A.

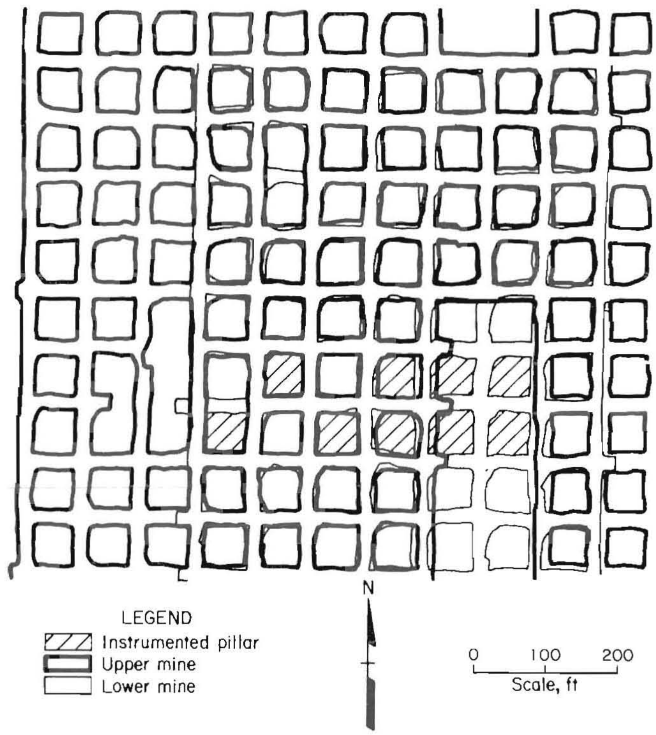

FIGURE 15.–Superpositioning of instrumented pillars at study mine B.

pillar (12). If the coalbed interval is less than eight times the pillar width, the pressure contour lines interact with respect to two superimposed pillars. The assumed pressure between superimposed pillars would be the sum of the two pressure contour lines. The smaller the interval is between coalbeds, the larger the sum of resulting pressure. Additional pressure can be created from neighboring pillars, but a horizontal dissipation of pressure is minimized when workings are separated by less than two pillar widths (12). The total pressure from these interactions, along with their geomechanical properties, determines whether the strata between the coalbeds will fail or not.

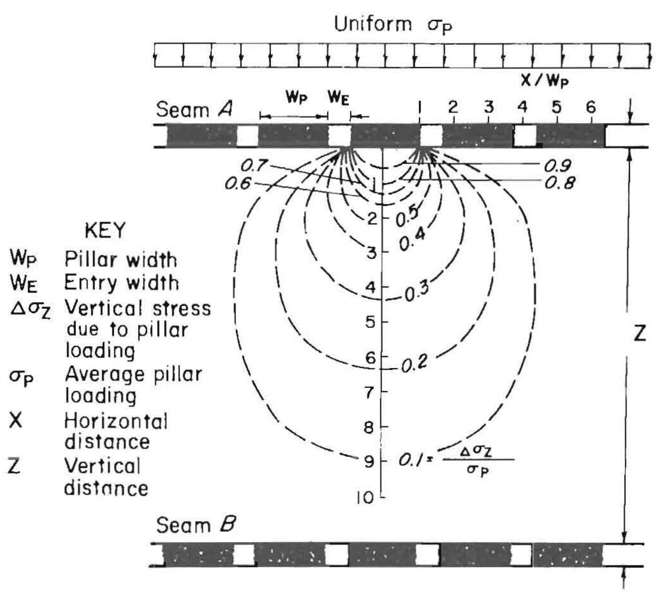

FIGURE 16.–Pressure-bulb analysis.

INSTRUMENTATION AND RESULTS

INSTRUMENTATION

The instrumentation installed included borehole platened flatjacks (BPF's) (13) and convergence stations. BPF's can measure relative increases in pillar pressure, but not actual pillar pressure. The BPF's were installed in the coal pillar with a setting pressure equal to the pillar pressure as calculated using the tributary area method (TAM) (5). This method utilizes such factors as overburden depth, innerburden thickness, and percent extraction. Removable convergence stations measure roof to floor convergence. Two reference pins are installed in the entry (the roof and the floor), and subsequent convergence is measured using a removable tube extensometer.

Figures 17 and 18 show the pillars selected for the study and instrument location for the upper and lower coalbeds respectively at study mine A. A total of 4 BPF's and 12 convergence stations were installed in the upper coalbed (fig. 17). BPF's at 30 and 10 ft were installed in the pillar on the right side of the track entry, and BPF's at 21 and 10 ft were installed on the left side of the track entry. Owing to the conditions present within the upper coalbed, BPF 3 was installed at a depth of 21 ft.

A total of 5 BPF's and 12 convergence stations were installed in the lower coalbed (fig. 18). Three BPF's were installed at depths of 30, 10, and 2 ft. BPF's at 30 and 10 ft were installed in the adjacent pillar. The estimated setting pressures, using the TAM, were calculated to be 1,200 psig in the upper coalbed and 1,300 psig in the lower coalbed. Actual setting pressures are shown in table 2. At the time of installation, setting pressures were determined from information provided using an overburden of 700 ft above the upper coalbed.

Through the construction of an overburden isopach map (fig. 6), the overburden depth was observed to be larger than the original figure. Figure 6 shows approximate overburden depth above the upper coalbed to be 960 ft. Therefore, with 40 ft of innerburden, the lower

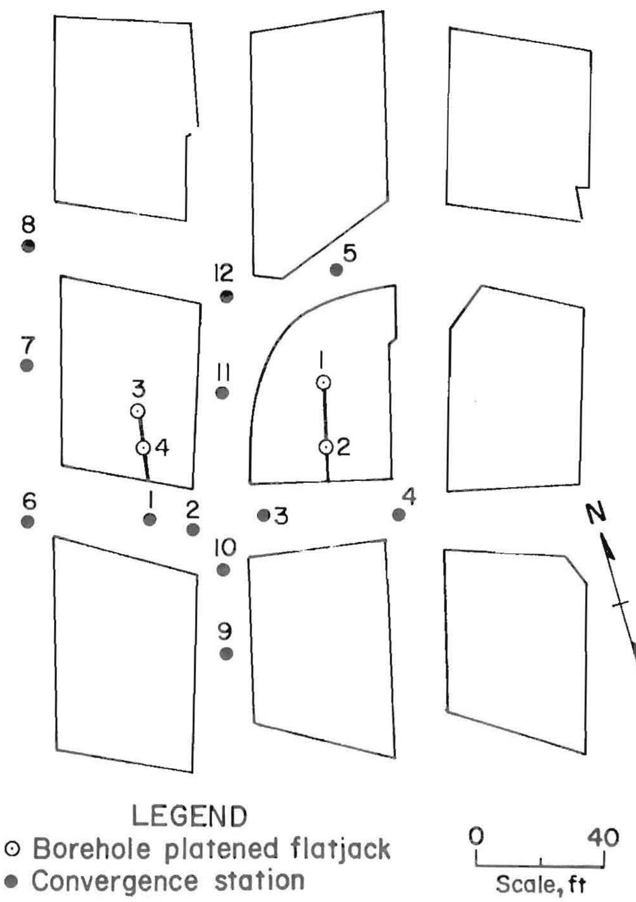

FIGURE 17.–Instrument location in upper coalbed for study mine A.

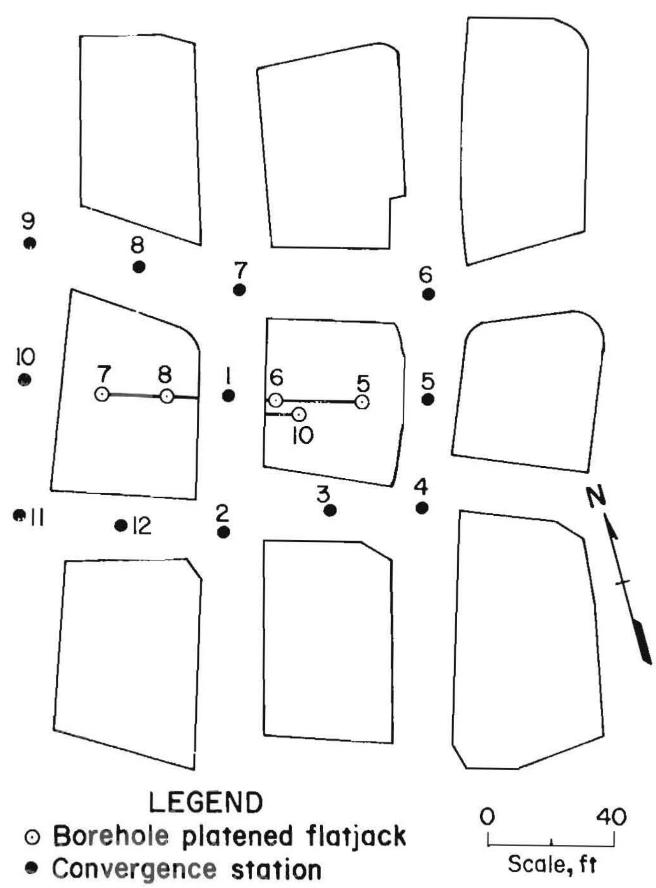

FIGURE 18.–Instrument location in lower coalbed for study mine A.

TABLE 2. - Flatjack (BPF) setting pressures for study mine A, pounds per square inch

BPF	Pressure
Upper coalbed:	
1	1,100
2	1,225
3	1,200
4	1,275
Lower Coalbed:	
5	1,300
6	1,000
7	1,300
8	1,300
10	1,200

TABLE 3. - Flatjack (BPF) installation depths for study mine B, feet

(All BPF setting pressures were 1,000 psi)

BPF	Depth	BPF	Depth
1	25	10	10
2	10	11	20
3	25	12	12
4	10	13	20
5	27	14	12
6	10	15	24
7	27	16	11
8	12	17	27
9	27	18	12

coalbed experienced an overburden depth of approximately 1,000 ft. Using the TAM and overburden depths of 960 and 1,000 ft for both mines respectively, setting pressures for the BPF's should have been 2,110 psig for the upper coalbed and 2,200 psig for the lower coalbed. Although the original setting pressures were low, these pressures do not directly affect the recorded results. It is also safe to assume that any increase in pillar pressure above 2,110 and 2,200 psig would be a result of relative increases in pillar pressure (5).

Figure 19 displays the selected pillars and instrument location for study mine B. A total of 18 BPF's and 21 convergence stations were installed in the lower coalbed to measure any relative increases in pillar pressure or entry closure due to overmining from the upper coalbed. The actual setting pressures and installation depths for all BPF's is shown in table 3.

RESULTS

Study Mine A

Monitoring of the instrumentation continued for 177 days. The instruments were monitored at least once a week. Table 4 displays BPF data for 44 days (25 pct of total period), 88 days (50 pct), and 177 days (total monitoring

TABLE 4. - Flatjack (BPF) pressures during 177-day monitoring period for study mine A, pounds per square inch

BPF	Initial (installation date)	Day 44 (25 pct of total period)	Day 88 (50 pct)	Day 177 (final)
UPPER COALBED				
1	1,100	8,100	8,100	8,100
2	1,225	950	900	950
3	1,200	3,175	4,050	5,100
4	1,275	1,200	1,250	1,250
LOWER COALBED				
5	1,300	1,090	1,050	1,050
6	1,000	880	850	850
7	1,300	1,050	1,000	1,050
8	1,300	900	900	900
10	1,200	1,000	1,000	950

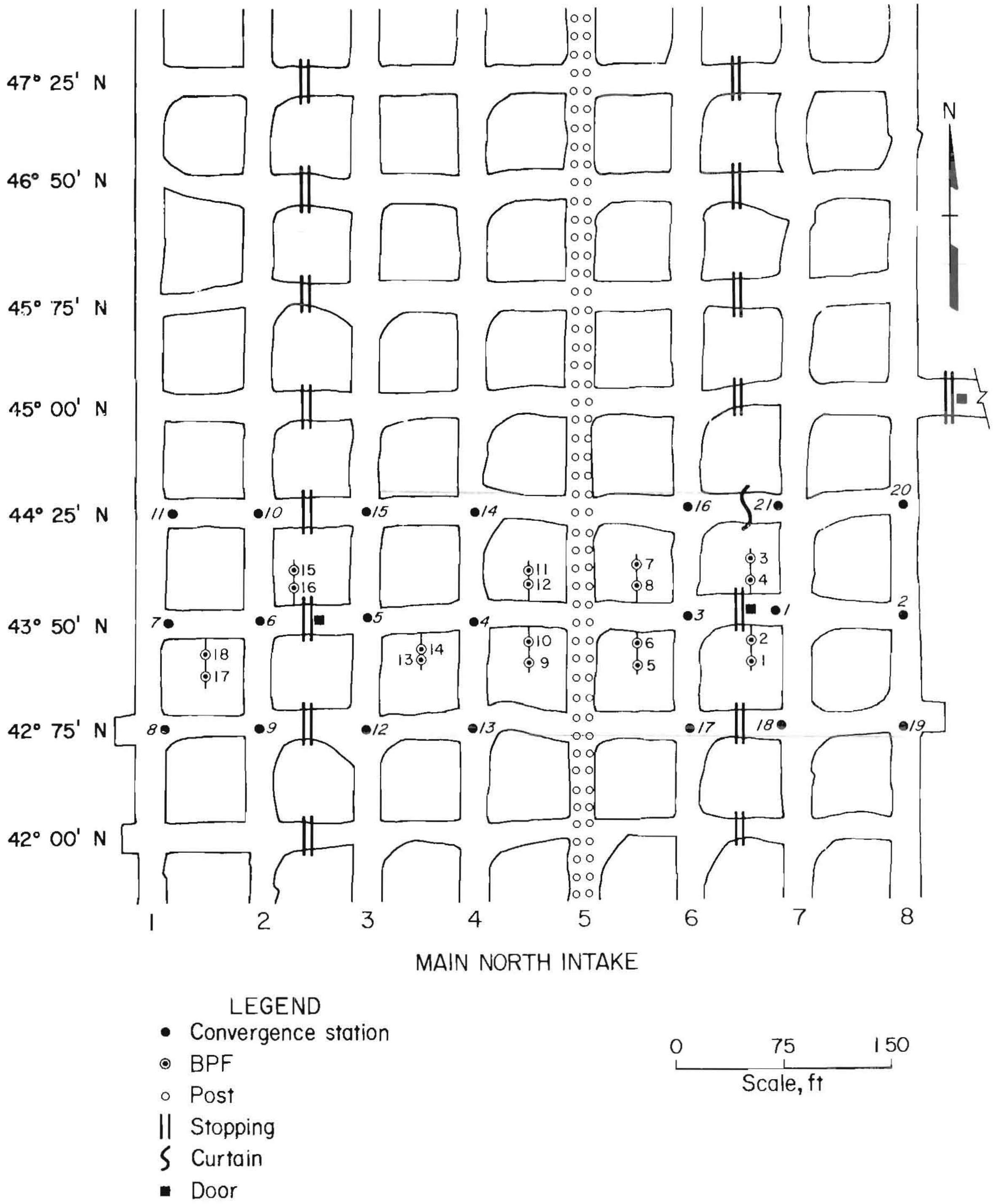

FIGURE 19.–Instrument location in lower coalbed for study mine B.

period) for the upper and lower coalbeds. BPF 1 and 3, both located in the upper coalbed at depths of 30 and 21 ft, respectively, displayed major increases in pillar pressure throughout the study. BPF 1, installed at 1,100 psig, increased to 4,500 psig 16 days into the study. BPF 3, installed at 1,200 psig, increased 2,500 psig, also 16 days into the study. Total pressures recorded from BPF 1 and 3 were 8,100 and 5,100 psig, respectively, resulting in pressure increases of 7,000 and 3,900 psig. Any increases in pillar pressure for the upper coalbed were from BPF's installed within the core of the instrumented pillars. A core type of loading is the worst type of loading to experience. Once a core loading occurs, this loading tends to transfer load more readily to other workings. The BPF's located at 10-ft depths showed no major increases in pressure. Figure 20 represents pressure increases versus time for all BPF's installed in the upper coalbed. No major increases in pillar pressure were recorded from BPF's in the lower coalbed.

Tables 5 and 6 show measured convergence for the upper and lower coalbeds. Monitoring of convergence in both mines was performed at least once a week. Maximum convergence of 5 in occurred at station 9, located in the track entry within the upper coalbed. Roof to floor convergence within the upper coalbed increased very rapidly. Measurements performed showed an average of 0.5 in of closure every month. No major roof to floor convergence was measured within the lower coalbed.

BPF and convergence installations were limited to more stable areas in the lower coalbed because of height restrictions. In unstable areas of the lower coalbed,

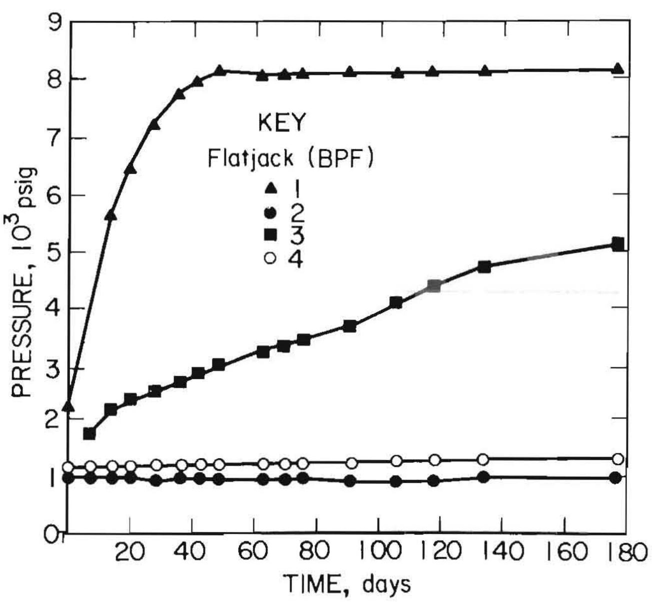

FIGURE 20.–Pressure increase versus time in upper coalbed for study mine A.

TABLE 5. - Results of convergence monitoring in upper coalbed for study mine A, inches

Station	Day 44	Day 88	Day 177 (final)
1.......	1.40	1.95	3.54
2.......	.84	1.25	2.13
3.......	ND	ND	ND
4.......	.60	1.29	[1]1.80
5.......	1.24	1.88	2.71
6.......	1.32	2.03	3.37
7.......	1.15	1.85	3.00
8.......	.81	1.26	2.08
9.......	2.23	3.26	5.00
10......	.94	1.31	2.12
11......	.80	1.13	1.92
12......	1.40	1.45	2.24

ND No data because station was destroyed.

[1]Monitoring discontinued on day 134 because of bad roof conditions.

TABLE 6. - Final convergence monitoring results for lower coalbed at study mine A, inch

Station	Convergence
1..........................	0.05
2..........................	.04
3..........................	0
4..........................	0
5..........................	0
6..........................	0
7..........................	.11
8..........................	.05
9..........................	.01
10.........................	0
11.........................	.13
12.........................	.04

NOTE.--No major movement occurred within the lower mine.

TABLE 7. - Flatjack (BPF) pressures during 177-day monitoring period for study mine B, pounds per square inch

(All BPF initial setting pressures were 1,000 psi)

BPF	Day 44 (25 pct of total period)	Day 88 (50 pct)	Day 177 (final)
1	925	950	1,000
2	900	925	1,000
3	825	825	875
4	925	900	950
5	925	950	975
6	875	900	975
7	900	900	900
8	550	575	600
9	875	900	900
10	925	925	975
11	925	875	875
12	1,000	925	950
13	850	825	825
14	900	1,275	1,675
15	750	725	675
16	900	900	900
17	900	900	850
18	775	800	900

the same type of pillar loading and roof to floor convergence would have been observed as was the case in the upper coalbed.

Study Mine B

Monitoring of the instrumentation was also performed once a week at study mine B. To date, monitoring of the instruments is still continuing, but for comparative purposes the time periods of 44 days (25 pct of total period), 88 days (50 pct), and 177 days (total monitoring period) will be used. Tables 7 and 8 represent the BPF pressure and convergence measurements.

The BPF that showed the highest pressure increase was BPF 14, located approximately 11 ft into the pillar or at the skin of the pillar. BPF 14 increased approximately 700 psig over original setting pressure. As opposed to core loading previously discussed, loading on the skin of the pillar tends to dissipate this load transfer over time. The results of convergence monitoring for the

TABLE 8. - Results of convergence monitoring for study mine B, inch

Station	Day 44	Day 88	Day 177 (final)
1	0.001	0.003	0.024
2	.000	.000	.000
3	.012	.068	.134
4	.000	.026	.072
5	.000	.000	.000
6	ND	ND	ND
7	ND	ND	ND
8	.003	.016	.054
9	ND	ND	ND
10	.009	.018	.034
11	.000	.015	.051
12	.010	.008	.034
13	.000	.000	.025
14	.012	.012	.033
15	.000	.000	.018
16	.007	.045	.154
17	.003	.011	.048
18	.000	.013	.033
19	.007	.019	.013
20	.004	.024	.036
21	.001	.019	.033

ND No data because station was destroyed.

total monitoring period (177 days) was minimal. Convergence stations 3 and 16 monitored the largest increases in roof to floor convergence, which was approximately 0.10 in. Average convergence for the 21 convergence stations installed was approximately 0.050 in for the total monitoring period (177 days).

As previously mentioned, core loading would tend to transfer load more readily, possibly causing severe problems in other workings. At study mine B, BPF 14 experienced a skin type of loading and roof to floor convergence was minimal. Whereas, at study mine A where BPF's experienced a core loading, roof to floor convergence was monitored at 5 in, considerably more movement than observed at study mine B.

CONCLUSIONS

Based on the information collected throughout this study, the following conclusions can be made.

Overburden depth above study mine A was approximately 1,000 ft. The overburden depth changed dramatically over the study section and reached a topographic high over the study area. Overburden depth above study mine B was approximately 555 ft, which is comparably smaller. Other case studies (4) have shown that excessive overburden depths could lead to unstable ground conditions.

Innerburden thickness at study mine A was approximately 40 to 45 ft, (less than one pillar width). Whereas, the innerburden thickness in study mine B was approximately 110 ft (or two pillar widths). Prior research has shown (4) that workings in close proximity, less than two pillar widths, may create ground control problems above and below workings.

Previous research also showed (4) that innerburden material, composed mostly of sandstone or a rock type with a high modulus of elasticity, tends to dampen the effects of pillar load transfer. The sandstone percentage at the study area for study mine A was approximately 77 pct. Whereas, the sandstone percentage at the study area for study mine B was approximately 6 pct, which is considerably smaller. According to Haycocks (4), 78 and 107 ft of innerburden thickness is required for stable conditions to exist in study mines A and B, respectively. Innerburden thickness with respect to the study area at study mine A was approximately 40 to 45 ft and innerburden thickness with respect to the study area at study mine B was approximately 110 ft.

At study mine A, floor heaving was observed in both sandstone and shale floor units. The shale floor, being a low-modulus material, resulted in hump-like floor heave, whereas the sandstone floor, being a high-modulus material, resulted in a buckling type of floor heave. No floor heaving was observed at study mine B.

At study mine A, the upper coalbed pillars were developed first, with the lower coalbed pillars developed approximately 2.5 yr later. For study mine B, the lower coalbed pillars were developed first, with the upper coalbed pillars developed approximately 2 yr later.

At study mine A, the practice of superpositioning was attempted, but mine overlays show pillars and entries were not superpositioned. Mine overlays for study mine B show that pillars and entries were superpositioned with equivalent dimensions.

The BPF pressure readings in the upper coalbed at study mine A showed a core loading characteristic of a stiff pillar approaching failure. The largest pressure reading monitored at a study mine B was from a BPF installed at the skin of the pillar. A skin loading would have a smaller chance of transfering load than pillars experiencing a core type of loading.

Average convergence in the upper coalbed entries at study mine A was 2.5 in, as compared to minimal convergence monitored at study mine B.

RECOMMENDATIONS

Based on the information and results collected throughout this study, the following recommendations could be made.

When overburden to innerburden ratios exceed 10:1, supplemental supports such as cribs and posts should be considered.

In those areas where floor heaving becomes excessive, regrading of the floor is a common, but an expensive means of contending with the problem. As an alternative solution, stress relief techniques such as floor slotting can be initiated to redistribute stress and provide a space for floor material to flow. This technique, however, should be applied before floor heave becomes excessive.

Prior research has shown (4) that the optimum mining sequence for mining one coalbed at a time would be to mine the uppermost coalbed first, leaving no pillars and then mine the next lower coalbed. In the case of mining simultaneously, the upper coalbed should be mined approximately two to three pillar widths ahead of the lower coalbed on advancement, and if retreat mining, the lower coalbed should be approximately two to three pillar widths ahead of the upper coalbed.

Superpositioning or columnization of pillars should be standard practice when dealing in multiple-seam design. Although very difficult to achieve, this practice requires total alignment of pillars that are similar in size and shape for both coalbeds.

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